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J. Korzeniowska, J. Joannou

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Systems Engineering in the Hot Seat

A Year-Long Transformation Programme to Bring Systems Engineering to the Hottest Place in the Solar System

Jessica Korzeniowska, UKAEA, Jessica.Korzeniowska@ukaea.uk

Jason Joannou, UKAEA, Jason.Joannou@ukaea.uk

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Abstract

This paper describes a case study in seeking to encourage widespread adoption of Systems Engineering at the UK Atomic Energy Authority. Until recently, the quest for fusion energy has primarily been in the scientific research domain, but with a shift in focus to delivering commercially viable fusion power plants, there is a clear need for Systems Engineering to help manage the resulting complexity. To help facilitate this transformation, a novel programme was created, entitled ‘A Year of Systems Engineering’, with a mission: To equip and empower everyone working in projects, across all disciplines at UKAEA, with the tools and basic level knowledge to use Systems Engineering in their day-to-day work. The 12-month programme, starting in June 2020, held regular online events featuring external and internal Systems Engineering experts, launched an intranet hub of Systems Engineering information, and created educational resources in response to specific needs in the organisation. Over the course of the programme, demand for Systems Engineering support on projects increased, resources were adopted into daily work, and feedback from staff indicated that they felt empowered to implement Systems Engineering principles on projects. Reports from customers also indicated they were thrilled with results from new Systems Engineering approaches being applied. The programme also reached the international fusion community, offering opportunities for increased collaboration and knowledge sharing around adopting Systems Engineering in the field. As well as reflecting on the programme, this paper considers the next steps required to further embed Systems Engineering at UKAEA, building on insights that were gained throughout the year. Finally, the paper identifies lessons learnt that may be applicable to other organisations embarking on a similar transformation journey.

Introduction

Fusion energy provides one of the most promising sustainable energy solutions to the world’s impending energy crisis. Fusion is the process that powers the Sun, where light nuclei fuse together to form a heavier nucleus and a vast amount of energy. Harnessing this energy to provide electricity has been the subject of research for many years and is often thought of as the ‘ultimate energy source’, as it is continuously available, with plentiful fuels available from sea water, and is an inherently safe process. The UK Atomic Energy Authority (UKAEA) is the UK’s national fusion

laboratory with the mission ‘of positioning the UK as a leader in sustainable nuclear energy’ [gov.uk 2021]. The authority has around 2000 staff working across all different aspects of fusion research including plasma physics, materials, remote maintenance, and future power plants. UKAEA hosts the world’s leading fusion experiment, the Joint European Torus, or JET, which reaches temperatures of 150 million degrees Celsius during operation – making it the hottest place in the solar system.

Until recently, the quest for fusion energy has primarily been in the scientific research domain, but with a shift in focus to delivering commercially viable fusion power plants, there is a clear need for Systems Engineering to help manage the resulting complexity. At UKAEA, there has been a significant increase in the demand for Systems Engineering over the last few years, with the group growing from approximately five systems engineers to 20 – a large portion of these deployed to commercial reactor projects such as STEP [ukaea.uk 2021] and DEMO [euro-fusion.org 2021].

In the past, however, whilst the basic need for Systems Engineering was understood, it was not appreciated sufficiently to fully integrate Systems Engineering into the core of projects. Systems Engineering often took place at the periphery, with many in the project unaware of the work being done, thus severely limiting its value. Systems engineers struggled to engage meaningfully and implement good practices. Simply put, few people across the organisation knew what Systems Engineering was and how it could practically support the mission of realising fusion energy. Previous attempts to address these issues over the years have had limited impact.

In response to these issues, and after a consultation in November 2019 with the Systems Engineering Group to assess the root causes of problems, a proposal for a programme to increase engagement of the wider organisation with Systems Engineering practices and the group was developed. This would serve as a first step in embedding Systems Engineering at UKAEA, by increasing the baseline level of understanding of Systems Engineering across the organisation and paving the way for formal processes to be introduced later.

The Aims

This paper describes the implementation and impacts of a year-long engagement programme to encourage widespread adoption of Systems Engineering at UKAEA. Specifically, the following areas will be examined:

- The original proposal for the programme and its realisation, examining elements of Events, Training, and Intranet Resources.
- Results from the programme and the transformative impact it had on Systems Engineering culture at UKAEA.
- Lessons learnt that may be applicable to other organisations embarking on a similar transformation journey.
- The next steps required to further embed Systems Engineering at UKAEA, building on insights that were gained throughout the year.

Approach

The engagement programme that was developed, called ‘A Year of Systems Engineering’, had the overall aim:

To equip and empower everyone working in projects, across all disciplines at UKAEA, with the tools and basic level knowledge to use Systems Engineering in their day-to-day work.

It was hoped that the results from this programme would include:

- Increased awareness and appreciation of Systems Thinking principles amongst non-technical staff.
- Increased baseline knowledge and use of Systems Engineering techniques and tools amongst technical staff.
- Better Systems Engineering practices across UKAEA and more consistency in approaches.
- Feedback upon which to build formal UKAEA Systems Engineering processes.

Proposal

Over 12 months, the Systems Engineering Group would deliver a programme of training and engagement activities for all those on site in an attempt to tackle the historic limited engagement and application of Systems Engineering at UKAEA. The programme plan also included a preparatory phase before the start of the formal year where the necessary systems (Intranet area, process for dealing with incoming support requests) were set up, and the group collected a database of expertise and resources to be used throughout the programme. This phase lasted approximately three months.

The plan was developed using feedback from the consultation session with the Systems Engineering Group and from external systems engineers who had run similar activities in the past at both Princeton Plasma Physics Lab and the MOD. They had respectively seen lunch and learn type sessions, with relevant Systems Engineering topics, and one day training workshops, in a variety of systems subjects, work well. The proposed programme consisted of three main elements: an Intranet Area, Events, and Training Workshops. Each was geared towards a particular user with different needs for the level of technical detail and Systems Engineering knowledge. This is displayed in Figure 1.

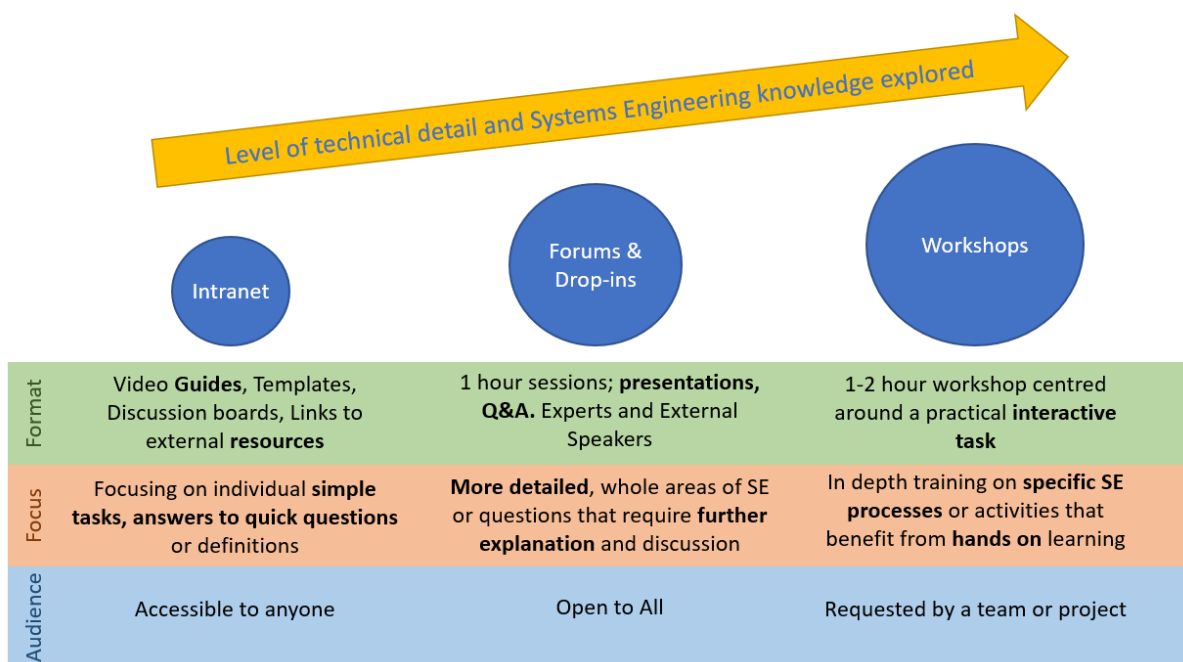


Figure 1 - Elements of the Year of Systems Engineering Programme, with intended focus and audience.

The intranet area was to be a store of information, video guides, templates, and FAQs, as well as links to recommended external Systems Engineering resources such as SEBOK [sebokwiki.org 2020] and the INCOSE UK zGuides [incoseuk.org 2021]. The video guides were to be created by the Systems Group, using formal Systems Engineering materials such as the INCOSE handbook [INCOSE 2015] and the Burge Hughes Walsh online 'Tool Boxes' [burgehugheswalsh.co.uk 2020] as references for good practice. As presentations were given through the year at the events, these would also be uploaded to the area as a resource. Throughout the year, more content would be released regularly. The intranet would also have a contact form where staff could request Systems Engineering support on a project or submit queries.

Events would be held once per month with either of two formats:

- Systems Engineering Forum: a formal presentation of material either from an internal speaker in the Systems Engineering Group, or an external speaker working on Systems Engineering activities in another high-tech industry.
- Doughnut Drop-In session: a Q&A format where participants are promised a doughnut in return for every question or discussion point they raise. Each drop-in would have a theme, with experts from the Systems Engineering Group joining to discuss that particular area, but all Systems Engineering questions would be welcome.

Lastly, workshops were envisaged to be focused hands-on sessions, requested by teams, where the Systems Engineering Group would provide training in a specific area, perhaps Systems Thinking, requirements writing, or interfaces. It was also hoped that a computer-based training module in Systems Thinking would be developed to be rolled out to all new starters. A Graduate Training course, which had been piloted a year previously but now had to be updated and moved online due to the pandemic, also fell under this category. By the end of the year it was hoped that the Systems Engineering Group would have a portfolio of training and workshops that could be delivered on request to address specific needs of teams throughout the organisation.

Realisation

The 'Year of Systems Engineering' began in June 2020, with a virtual launch event, having moved online due to the COVID-19 pandemic. All subsequent events also took place online as the organisation continued to work from home.

The intranet area went live at the virtual launch event, with a selection of pre-loaded content. Further content was uploaded throughout the year; however, due to time constraints, it became increasingly difficult to create original resources, such as video guides, within the group. Instead, external resources were uploaded where possible. This was helpful, but it would have been preferable to create original resources that could have been tailored to the needs of UKAEA.

The monthly events were the most successful and memorable aspect of the programme. They served to keep the momentum going and provide a focus throughout the year. The programme welcomed speakers from organisations such as Martin Baker Aircraft, Optima Systems Consultancy with SA Group, and Animal Dynamics.

In September, a special 'Requirements Month' event took place where new requirements resources were released each week, culminating in a forum with an internal speaker at the end of the month. In December, an interactive group competition style forum 'How the Grinch Systems Engineered Christmas' was run, to give an opportunity to put into practice some of the skills and methods that had been covered so far in the programme.

Forums had an average attendance of around 70 people. Doughnut drop-ins grew something of a cult following, with a small but dedicated group consistently showing up to discuss. The author of this paper is now in a significant amount of 'doughnut debt'. Drop-ins were attended by around 30 people each time.

The workshops aspirations for the programme were not fully realised, primarily due to budget and time constraints. For similar reasons, the hands-on sessions as well as the computer-based training module were not achieved. There were requests for Systems Engineering talks and training sessions from a variety of departments; however, many of these have not yet been delivered. Despite this, the online graduate training course that was developed, 'Adventures in Systems Engineering' was run three times over the course of the year. Two year groups of graduates took the course in addition to a group of summer placement students, who specifically requested it after hearing the feedback from the graduates – in total 83 students. The course was delivered in a choose your own adventure format with a fantasy theme and had excellent feedback from each of the three groups, indicating graduates felt empowered to use Systems Engineering techniques in their work after the course.

Result

Feedback from a sample of 41 participants at the end of the year indicated that the base level of knowledge of Systems Engineering did increase as intended (Figure 2 and Figure 3). 46.2% of the sample group reported that they sought the help of a systems engineer, or used a Systems Engineering technique in their work as a result of something they saw in the programme. Many gave examples of where they had adopted the resources or techniques promoted in their day-to-day work.

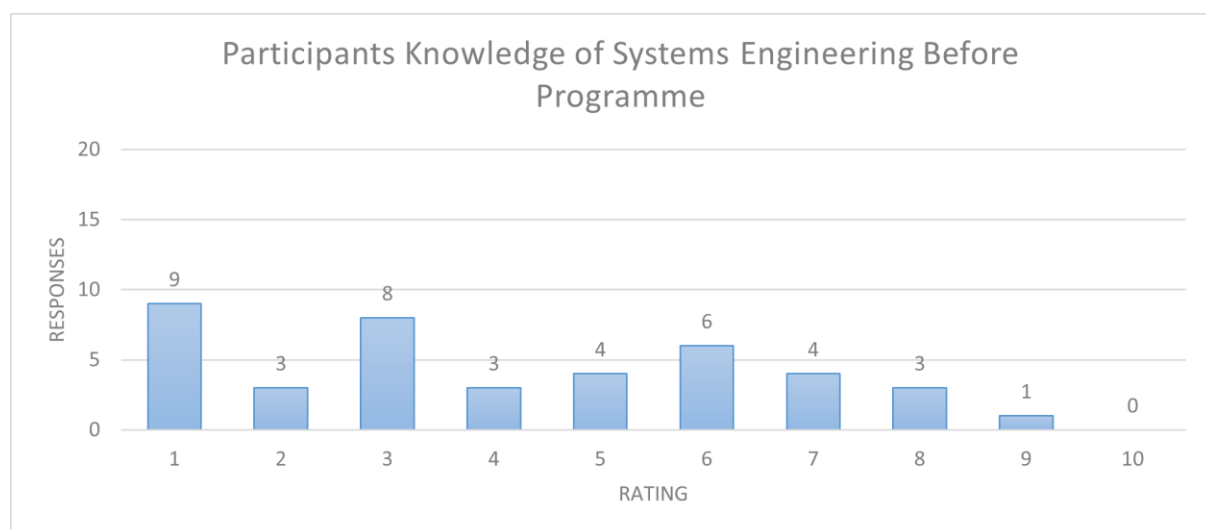


Figure 2 – Results from asking 41 survey respondents 'On a Scale of 1 to 10, how would you have rated your knowledge of Systems Engineering BEFORE the Year of Systems Engineering Programme?'

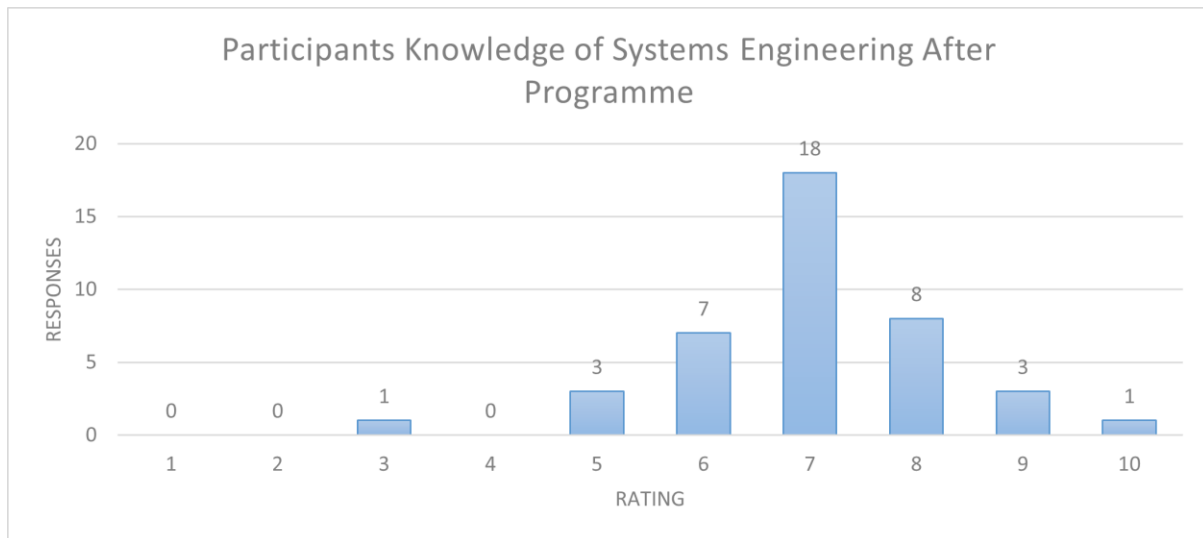


Figure 3 – Results from asking 41 survey respondents ‘On a Scale of 1 to 10, how would you rate your knowledge of Systems Engineering now?’

The sample were also asked to describe the Systems Engineering culture at UKAEA before the start of the programme and any changes since then, with responses reporting they largely experienced positive changes.

Key themes from responses to ‘*How would you describe the Systems Engineering culture at UKAEA before June 2020?*’ included: low knowledge; limited to systems engineers; some appreciation in places, but not widely adopted or fully engaged with projects; Systems Engineering considered a burden; group were not widely known.

Key themes from responses to ‘*Have you experienced any changes in projects or Systems Engineering culture at UKAEA since June 2020?*’ included: more awareness both personally and in projects; bigger presence of systems engineers; project management and leaders have been more willing to use Systems Engineering techniques; need for requirements and Systems Engineering support has been taken more seriously in some areas.

Wider Impacts

Beyond the initial results and increase in awareness, the programme has had positive impacts in many other areas:

- There has been a notable increase in demand for Systems Engineering support on projects. In some cases, this was a direct result of conversations at events.
- Where Systems Engineering is now being applied as a result of the programme, positive feedback has been received. For example, in one case the work was so successful it was presented to senior EUROfusion management as an example of a recommended approach for similar studies.
- A Requirements Working Group has been set up in the Systems Engineering Group in response to insights gained during the Requirements Month event. The group will look at consolidating different approaches to requirements around site into one formal approach.

- Several graduates have now asked for secondments to the Systems Engineering Group after taking the training. A placement student is returning in Summer 2021 to take a new placement in Systems Engineering.
- Later in the programme, events were attended by external UKAEA partners from across Europe (Fusion for Energy, ITER, Max Planck Institute) and this led to knowledge sharing between fusion organisations around similar kinds of issues that were happening. A ‘Systems Engineering in Fusion Network’ has been set up as an outcome of the programme, to build on these relationships and continue knowledge sharing and collaboration on Systems Engineering approaches across the international fusion community.

Lessons Learned

Key takeaways from the running of the programme are described below. These may be of interest to other organisations considering similar transformation programmes.

- External speakers, showing their use of Systems Engineering on cutting edge technology was highly effective at engaging staff. These events were by far the most popular activity of the programme, with the highest attendance figures out of all the events. 81% of the participant sample responded that they had attended one of these sessions, and they featured most commonly in feedback about the most enjoyable aspects of the programme.
- Visibility of the Systems Engineering team is vitally important. Despite having online forms and forums to get in contact or ask questions, these were rarely used. Much more often, systems engineers were contacted directly for help. Speaking to a human seemed to be preferable, and so it was important to ensure people knew who they could go to.
- The approach taken in this programme was successful in engaging widely within the organisation. However, effective engagement with senior leadership would likely require additional, more targeted events.
- Developing and running this programme could have easily filled a full-time role. Having backing from management with respect to dedicated time and budget for the work was crucial.
- A dedicated champion is needed to drive the programme. There had been much discussion of running initiatives like this in the past, but little happened until a group member took responsibility.

Next Steps

Moving forward, several next steps have been identified to further the work of the programme and continue to work to embed Systems Engineering at UKAEA:

- This programme has primarily addressed culture and understanding of a Systems Engineering approach. A key next step is to build upon these foundations, laid in the Year of Systems Engineering, through developing and implementing high level Systems Engineering processes and tools. To maintain traction, it is important that Systems Engineering processes and tools are tailored to the UKAEA context. Fusion has to deal with a lot of uncertainty which needs to be addressed in the Systems Engineering approach.

- Engage with other organisations to share lessons learnt from other experiences of embedding Systems Engineering. The Systems Engineering Group has already begun discussions with AWE and also plans to build on relationships with organisations that participated in the programme.
- Work to formally define the role of a systems engineer within projects at UKAEA, being more specific about the responsibilities of a systems engineer on a project compared with other roles such as project manager and lead engineer. This question came up multiple times in discussions throughout the programme and is important to clarify moving forward.
- Re-examine the workshops and training element that was unable to be completed this year, for example develop a Systems Thinking course. In the meantime, the graduate training course will be rolled out widely to staff, as a first step in providing basic systems engineering training to staff.
- Requirements were the only aspect of Systems Engineering that were given their own dedicated focus through 'Requirements Month' as it was a key area of interest for current work at UKAEA. Moving forward to any future drives or events, other aspects such as interface management and verification could also benefit from a specific focus: UKAEA is working to develop interface management approaches for both the DEMO and STEP reactors; we have also been asked to renew our verification procedures to align with new regulations for UK Conformity Assessed marking. A focus on these Systems Engineering aspects would support the success of both these new endeavours at UKAEA.
- Lastly, it is important to continue exploring what can be done to make Systems Engineering more accessible to non-systems engineers. A simple example of this would be to develop a UKAEA systems engineering glossary. Another example would be to develop UKAEA case studies of where the sensitive application of Systems Engineering has demonstrably added value in different types of project, ranging from design of new power plants to much smaller upgrade projects.

Conclusion

This paper has summarised the Year of Systems Engineering Programme implemented by UKAEA, showing how it triggered a shift in Systems Engineering culture through a suite of activities and resources over the course of a year. Lessons learned as well as next steps have been identified.

Overall, the programme was a huge success. The aim to equip staff with a basic level of Systems Engineering knowledge was achieved, and results show that they feel empowered to use it in their day-to-day work. It has not only set off a transformation in attitudes towards Systems Engineering but has also provided the group with more information on what needs to be tackled next to further embed Systems Engineering into UKAEA culture. It has given a platform for new collaborations and knowledge sharing opportunities with others in fusion and beyond. Putting Systems Engineering in the hot seat at UKAEA this year has had far-reaching benefits and has brought the organisation a step closer to fully embedding Systems Engineering in its mission towards realising fusion power.

Acknowledgements

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